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VITAMIN D STATUS AND SUPPLEMENTATION IN DENTAL IMPLANT OUTCOMES: A NARRATIVE REVIEW

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ABSTRACT

Introduction: Dental implant therapy is widely used in modern restorative dentistry. However, its success depends on effective osseointegration, which may be influenced by systemic factors such as vitamin D status. Vitamin D plays a key role in bone metabolism, calcium-phosphate homeostasis, and immune regulation, all of which are essential for proper bone healing.
Methods: This narrative review synthesizes current evidence on the role of vitamin D in dental implant osseointegration and outcomes. A literature search was conducted using PubMed, Google Scholar, and ResearchGate databases, focusing on studies published between 2020 and April 2026. Clinical trials, observational studies, and systematic reviews were included, and data were analyzed narratively.
Results: The analyzed studies demonstrated heterogeneous findings. Most evidence suggests that adequate serum vitamin D levels and supplementation in deficient individuals may improve early implant stability and peri-implant bone healing. Vitamin D deficiency has been associated with impaired osseointegration and an increased risk of early implant failure. However, several studies did not confirm a statistically significant relationship. Additionally, emerging evidence indicates that excessively high vitamin D levels may also negatively affect implant outcomes.
Conclusions: Most available evidence suggests that adequate vitamin D levels may support osseointegration, bone remodeling, and implant stability, while deficiency is associated with impaired healing and an increased risk of complications. However, the overall findings remain heterogeneous, and both insufficient and excessive levels may negatively affect outcomes. Assessment of vitamin D status prior to implant placement may therefore be beneficial, particularly in patients at risk of deficiency. Further well-designed clinical studies are required to establish optimal serum 25(OH)D levels and evidence-based supplementation protocols.

KEYWORDS

Vitamin D, Dental Implants, Osseointegration, Implant Failure, Bone Healing, Vitamin D Deficiency

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1. Introduction

Dental implants are widely used in modern restorative dentistry as a predictable and long-term solution for the rehabilitation of missing teeth. This form of treatment represents not only a clinical procedure but also a component of modern healthcare systems that integrate advanced technologies with patient-related systemic and socio-environmental factors. The increasing reliance on implant-based rehabilitation reflects broader trends in healthcare accessibility, aging populations, and lifestyle-related conditions that influence treatment outcomes. They provide significant functional and aesthetic benefits, including improved masticatory function, speech, and overall quality of life. Due to their high success rate, reported to exceed 85-95% after ten years, and increasing patient demands, implant therapy has become a standard treatment option for partial and complete edentulism (Kupka et al., 2024; Tallon et al., 2024).

The success of dental implants depends on osseointegration, defined as a direct structural and functional connection between bone tissue and the implant surface (Werny et al., 2022; Buzatu et al., 2024). Disruption of this process, whether due to biological or systemic factors, may result in reduced bone-to-implant contact (BIC) or early implant failure (Werny et al., 2022). While traditional research has mainly focused on local and mechanical factors, increasing attention has been directed toward systemic influences, including nutritional status and metabolic conditions (Sodnom-Ish et al., 2026).

Among systemic factors, vitamin D has emerged as a particularly relevant modulator of bone health and osseointegration (Werny et al., 2022; Buzatu et al., 2024). It is a fat-soluble vitamin mainly produced in the skin through sun exposure, with additional intake from diet and supplementation (Tallon et al., 2024). It exists in two main forms, vitamin D2 (ergocalciferol) and vitamin D3 (cholecalciferol), both of which undergo

enzymatic activation in the liver and kidneys to form biologically active metabolites (Tallon et al., 2024). Vitamin D plays a crucial role in calcium and phosphate homeostasis, stimulates osteoblastic activity, and regulates osteoclastic resorption, thereby contributing to bone remodeling and mineralization (Tallon et al., 2024; Werny et al., 2022). Additionally, review-based evidence suggests that vitamin D may enhance bone regeneration by promoting the differentiation of precursor cells into osteoblasts and supporting new bone formation, which is essential for effective osseointegration (Muresan et al., 2022). Beyond its role in mineral metabolism, vitamin D also modulates immune responses and contributes to maintaining bone integrity and proper healing of osseous defects (Muresan et al., 2022). Moreover, evidence suggests that adequate vitamin D levels, often in combination with calcium, may reduce bone resorption and support bone density, thereby promoting overall skeletal stability (Sundar et al., 2023).

Serum 25(OH)D levels are commonly used to assess vitamin D status, with concentrations below 20 ng/mL considered deficient, 20-30 ng/mL insufficient, and values above 30 ng/mL generally regarded as sufficient (Płudowski et al., 2023). In cases of deficiency, vitamin D supplementation is recommended, typically in the range of 800-2000 IU daily for maintenance, with higher doses used for correction under medical supervision (Płudowski et al., 2023). Adequate levels of vitamin D are essential for maintaining bone density and promoting effective bone healing (Muresan et al., 2022; Tallon et al., 2024). In contrast, vitamin D deficiency has been associated with impaired bone formation and compromised osseointegration, which may increase the risk of implant failure (Werny et al., 2022; Buzatu et al., 2024).

However, some evidence suggests that excessively high levels of vitamin D may also adversely affect peri-implant bone stability, highlighting the complexity of a potentially non-linear dose-response relationship between vitamin D status and implant outcomes (Cheng et al., 2024).

The clinical relevance of this issue is further emphasized by the widespread prevalence of vitamin D deficiency worldwide, affecting approximately one billion individuals, particularly among populations commonly undergoing implant therapy (Buzatu et al., 2024; Płudowski, 2023).

Vitamin D deficiency represents an important public health concern, and expert recommendations suggest targeted screening in risk groups rather than routine population-wide testing. Individuals at increased risk of vitamin D deficiency include older adults, patients with limited sun exposure due to indoor lifestyles or cultural factors, and those living in higher latitudes or areas with reduced ultraviolet radiation. In addition, metabolic disorders such as obesity, chronic liver or kidney disease, and malabsorption syndromes may impair vitamin D metabolism and bioavailability (Płudowski et al., 2023). Nutritional factors, including low dietary intake or restrictive diets, may further contribute to inadequate levels. Serum 25(OH)D is considered the standard marker of vitamin D status, while vitamin D3 supplementation is recommended when deficiency is identified or when adequate levels cannot be maintained through sunlight exposure and diet alone (Płudowski et al., 2023). Recent advances in diagnostic technologies, including rapid in-office vitamin D testing devices, may facilitate timely assessment of vitamin D status and support more personalized clinical decision-making in implant dentistry (Paz et al., 2021).

Despite growing interest in this topic, the relationship between vitamin D status and dental implant outcomes remains incompletely understood, with conflicting evidence reported in the literature (Werny et al., 2022; Buzatu et al., 2024).

Therefore, the aim of this narrative review is to evaluate the impact of vitamin D on the osseointegration of dental implants and to determine whether its deficiency or supplementation may influence implant outcomes.

2. Methodology

This narrative review synthesizes current evidence on the role of vitamin D in dental implant osseointegration and implant outcomes. A literature search was conducted using PubMed, Google Scholar, and ResearchGate databases. Combinations of keywords were used, including "vitamin D", "dental implants", "osseointegration", "implant failure", "bone healing" and "vitamin D deficiency".

The search focused on recent literature published between 2020 and April 2026. Only articles published in English were included.

Titles, abstracts, and full-text articles were screened for relevance. Priority was given to original clinical studies, randomized controlled trials, and observational studies evaluating the relationship between vitamin D status and implant outcomes. Systematic reviews and meta-analyses were also included to provide broader context. Studies focusing exclusively on animal models or in vitro experiments were excluded from the clinical synthesis, unless they were used to provide mechanistic background.

Data were extracted regarding study design, patient characteristics, vitamin D status or supplementation, and key outcomes such as implant stability, bone-to-implant contact (BIC), peri-implant bone loss, and implant survival.

Findings were synthesized narratively, with attention to consistency, methodological quality, and limitations across studies. All citations were managed in accordance with APA 7th Edition guidelines. This review is limited by the heterogeneity of included studies, variability in vitamin D assessment methods, and differences in outcome measures.

3. Results

3.1 Positive effects of vitamin D on implant stability and osseointegration

The majority of included studies demonstrated a positive association between vitamin D status and early implant stability, osseointegration, and peri-implant bone healing.

A prospective clinical study including 20 patients demonstrated a significant positive relationship between serum vitamin D levels and implant stability, with mean ISQ values increasing from 56.06 ± 5.83 at 3 months to 67.51 ± 6.17 at 6 months ($p < 0.001$). A strong correlation was observed at 3 months ($r = 0.54$), which increased to a strong correlation at 6 months ($r = 0.66$). Linear regression analysis further showed that each 1 ng/mL increase in vitamin D level was associated with a significant increase in ISQ of 0.48 at 3 months and 0.62 at 6 months ($p = 0.01$ and $p = 0.002$, respectively) (Bhandage et al., 2022).

Similarly, in a randomized controlled trial involving 40 patients with vitamin D insufficiency, supplementation with 5000 IU of vitamin D3 daily for 12 weeks was associated with significantly greater implant stability after 3 months compared with the control group, as reflected by higher median ISQ values (75 vs. 62; $p = 0.001$) and more frequent bone regeneration (Singh et al., 2025).

Comparable findings were reported in another experimental study involving 20 vitamin D-deficient patients, in which individuals receiving vitamin D3 supplementation showed significantly greater implant stability at both 3- and 6-month follow-up ($p < 0.05$). The supplementation protocol included 60,000 IU weekly for 8 weeks, followed by 60,000 IU monthly for an additional 16 weeks. Although a trend toward reduced crestal bone loss was observed in the supplemented group, the difference did not reach statistical significance. No significant differences were found in bone density between the groups at any time point (Ramalakshmi et al., 2026).

Further evidence supporting the beneficial role of vitamin D was provided by a prospective randomized controlled clinical trial including 122 patients. Patients with serum 25-hydroxycholecalciferol levels below 30 ng/mL received vitamin D supplementation at a dose of 8000 IU daily for 12 weeks. Higher baseline serum 25-hydroxycholecalciferol levels were significantly associated with greater peri-implant bone levels at both 6 and 12 weeks. Moreover, patients receiving vitamin D supplementation demonstrated significantly higher bone gain after 12 weeks compared with non-supplemented vitamin D-deficient individuals (Kwiatek et al., 2021).

Another prospective clinical study including 32 vitamin D-deficient patients compared crestal bone levels around implants in individuals receiving vitamin D3 supplementation with those who did not receive supplementation. Patients supplemented with cholecalciferol demonstrated more favorable crestal bone level changes, although most intergroup differences were not statistically significant. The authors concluded that vitamin D3 may support bone formation around titanium implants and contribute to osseointegration in deficient patients (Garg et al., 2020).

In a randomized clinical trial involving 24 immediate implants, topical application of vitamin D3 (calcitriol) gel was associated with improved clinical and radiographic outcomes after 6 months. Compared with the control group, the vitamin D group demonstrated significantly higher implant stability, with ISQ values reaching 80 versus 75, as well as greater peri-implant bone density. In addition, patients treated with topical vitamin D showed lower probing depth, reduced bleeding index, and lower postoperative pain scores, suggesting improved peri-implant soft tissue healing and patient comfort. These findings indicate that topical vitamin D3 may support both hard and soft tissue healing in immediate implant placement (Ayyad et al., 2025).

Likewise, a prospective clinical study conducted on 108 patients with 128 implants identified serum vitamin D3 concentration as the only factor significantly associated with successful osseointegration after 4 months, whereas bone density and insertion torque showed only weak relationships with treatment outcomes. Furthermore, the only two implant failures were observed in patients with extremely low vitamin D3 levels (<5 ng/mL) (Al-Quisi et al., 2024).

Similarly, a retrospective clinical study involving 30 patients demonstrated a significant association between serum vitamin D levels and crestal bone loss assessed by CBCT over a 6-month follow-up period,

with greater bone loss observed in the vitamin D-deficient group compared with individuals with normal vitamin D levels (Singh et al., 2023).

Paz et al. (2021) evaluated a 6-week pre-surgical supplementation program in 20 patients requiring implant therapy. At baseline, 65% of participants had vitamin D levels below 30 ng/mL. After supplementation, mean vitamin D levels increased from 24.76 ng/mL to 50.11 ng/mL, and antioxidant scores increased by approximately 54%. Although implant failure was not directly compared between groups, the study supports the feasibility of preoperative vitamin D optimization before implant placement (Paz et al., 2021).

3.2 Vitamin D deficiency and risk of early implant failure

Available evidence suggests a possible association between vitamin D deficiency and early implant failure. A prospective observational study including 143 implant sites in 53 patients found a markedly higher rate of early implant failure in individuals with severe vitamin D deficiency (<10 ng/mL) compared with those with insufficient (10-30 ng/mL) and sufficient (>30 ng/mL) vitamin D levels (46.2%, 2.3%, and 4.5%, respectively; $p = 0.0007$). In addition, the vitamin D-deficient group demonstrated lower bone density and ISQ values compared with the remaining groups (Mohsen et al., 2024).

3.3 Lack of significant association between vitamin D and implant outcomes

In a study including 109 patients and 174 implants, no statistically significant association was found between serum vitamin D levels and early implant failure during the 3-6-month follow-up period. Interestingly, the mean vitamin D level was higher in patients who experienced implant failure compared with those with successful outcomes (Francis et al., 2024).

Likewise, in a prospective observational study involving 166 patients and 556 implants, serum vitamin D levels were not significantly associated with short-term implant loss during the 12-month follow-up ($p = 0.286$) (Grigoraș et al., 2025).

These findings indicate that, although vitamin D may influence early healing and implant stability, its role in predicting implant failure remains inconsistent across studies.

3.4 Molecular and inflammatory aspects

At the molecular level, additional evidence was provided by a case-control clinical study involving 42 participants. Vitamin D-insufficient patients showed higher peri-implant crevicular fluid (PICF) RANKL levels, both in terms of concentration and total amount, together with lower IL-10 levels compared with individuals with adequate vitamin D status; both differences were statistically significant ($p < 0.05$). No significant differences were observed in the remaining evaluated biomarkers or bone tissue parameters (Toy et al., 2025).

These findings indicate a potential association between vitamin D insufficiency and a more pro-inflammatory peri-implant microenvironment.

3.5 Potential adverse effects of excess vitamin D

A retrospective case-control study including 73 patients and 291 implants reported that excessively elevated serum 25(OH)D concentrations (>70 ng/mL) may be associated with unfavorable implant outcomes. Patients with hypervitaminosis D presented a markedly higher risk of implant failure and severe peri-implant bone loss compared with individuals whose vitamin D levels remained within the intermediate range. In addition, this group demonstrated reduced long-term implant survival and faster peri-implant bone loss, particularly in implants placed in the maxilla (Cheng et al., 2024).

4. Discussion

The present narrative review suggests that vitamin D status may play an important, yet not fully consistent, role in the osseointegration of dental implants. The available clinical evidence indicates that both deficiency and excess of vitamin D can influence bone healing and implant stability; however, the strength and consistency of this relationship vary across studies (Al-Quisi et al., 2024; Grigoraș et al., 2025). A general tendency can be observed indicating that low vitamin D levels may be associated with less favorable implant outcomes, particularly during the early stages of healing (Mohsen et al., 2024). This may reflect the biological role of vitamin D in bone metabolism, including its involvement in calcium and phosphate homeostasis, stimulation of osteoblastic activity, and regulation of bone remodeling processes. At the same time, the relationship between vitamin D status and implant success is not consistently confirmed. While some clinical

studies suggest that low serum vitamin D levels may be associated with impaired osseointegration or increased risk of early implant failure (Mohsen et al., 2024; Al-Quisi et al., 2024), others have not demonstrated statistically significant associations between vitamin D levels and implant survival (Francis et al., 2024; Grigoraș et al., 2025).

This inconsistency suggests that vitamin D alone is unlikely to determine implant success and that its influence should be interpreted within a broader clinical context. It is likely that multiple interacting factors, including bone quality, surgical technique, implant design, and systemic health conditions, contribute to the final outcome of implant therapy. Within this multifactorial framework, vitamin D may act as a modifying factor rather than a primary determinant. This perspective helps to reconcile the variability observed across studies and supports a cautious interpretation of the available evidence.

4.1 Role of supplementation and baseline vitamin D levels

An important distinction emerges between the effects of baseline vitamin D status and the impact of supplementation. Current evidence suggests that correcting vitamin D deficiency may positively influence peri-implant bone conditions and healing dynamics (Kwiatek et al., 2021). For example, studies have shown that patients with deficiency who received supplementation exhibited improved bone levels around implants compared to non-supplemented individuals (Kwiatek et al., 2021). Similarly, adequate serum vitamin D levels have been associated with better preservation of crestal bone and more favorable peri-implant conditions (Singh et al., 2023). This is further supported by clinical findings reported by Garg et al. (2020), who observed improved crestal bone conditions in vitamin D-deficient patients receiving supplementation compared with non-supplemented individuals, although not all differences reached statistical significance. These findings indicate that vitamin D may play a supportive role in maintaining bone stability during the osseointegration phase (Ramalakshmi et al., 2026). However, the effect appears to depend on the initial vitamin D status of the patient. In individuals with sufficient vitamin D levels, the potential benefits of additional supplementation remain unclear, as this aspect has not been consistently addressed in the available clinical studies. This suggests that vitamin D supplementation may be most relevant in deficient patients and should be guided by prior assessment rather than applied universally.

4.2 Biological and molecular mechanisms

Vitamin D plays an important role in bone mineralization as well as in immune and inflammatory responses, which may influence the osseointegration of dental implants. This is further supported by review studies indicating that vitamin D enhances osteogenic differentiation and promotes new bone formation, which are key processes in implant integration (Muresan et al., 2022). These effects are closely related to its ability to regulate osteoblastic and osteoclastic activity, thereby contributing to bone remodeling. In addition, immune cells are among the first to interact with implanted biomaterials, and their activity plays a critical role in determining the outcome of implant integration. Vitamin D, as an immunomodulatory factor, may influence this early host response and thereby affect healing dynamics (Paz et al., 2021). The study by Toy et al. (2025) provides molecular insight into these processes, demonstrating that vitamin D insufficiency is associated with decreased levels of interleukin-10 (IL-10) and increased levels of RANKL in peri-implant crevicular fluid. This shift toward a pro-inflammatory and pro-resorptive environment may impair bone formation and negatively affect implant integration. These findings offer a plausible biological explanation for clinical observations suggesting that low vitamin D levels may compromise implant stability. Importantly, they indicate that vitamin D may influence not only bone mineralization but also the local inflammatory environment critical for successful osseointegration.

4.3 Deficiency versus excess: the importance of balance

An important consideration emerging from recent studies is the potential non-linear relationship between vitamin D levels and implant outcomes (Mohsen et al., 2024; Cheng et al., 2024). While deficiency is widely recognized as a potential risk factor, excessively high levels of vitamin D may also be associated with adverse effects (Cheng et al., 2024).

Evidence from retrospective analyses suggests that elevated serum vitamin D levels may be linked to an increased risk of implant failure and peri-implant bone loss (Cheng et al., 2024). Although the underlying mechanisms are not yet fully understood, these findings indicate that excessive vitamin D may disrupt normal bone metabolism or contribute to unfavorable remodeling processes (Cheng et al., 2024).

This highlights the importance of maintaining vitamin D levels within an optimal physiological range. The concept of a "therapeutic window" appears particularly relevant, suggesting that both insufficient and excessive levels may negatively influence implant outcomes (Mohsen et al., 2024; Cheng et al., 2024).

4.4 Clinical implications

From a clinical perspective, the available evidence supports the assessment of serum vitamin D levels prior to implant placement, particularly in patients at risk of deficiency (Al-Quisi et al., 2024). Identifying and correcting low vitamin D levels may contribute to improved early healing and implant stability, as deficiency has been associated with less favorable implant outcomes (Mohsen et al., 2024).

However, routine supplementation without prior evaluation cannot be universally recommended. The lack of consistent evidence supporting benefits in patients with sufficient vitamin D levels, combined with the potential risks associated with excessive vitamin D levels, underscores the importance of individualized patient management (Cheng et al., 2024). Clinicians should therefore aim to achieve optimal vitamin D levels rather than indiscriminate supplementation. Integrating vitamin D assessment into preoperative evaluation may represent a simple and practical strategy to optimize treatment outcomes. Additionally, simple in-office vitamin D testing methods may facilitate rapid assessment of vitamin D status in everyday clinical practice and support more individualized patient management (Paz et al., 2021).

Preoperative correction of vitamin D deficiency has been shown to be feasible and may contribute to improved peri-implant conditions. A 6-week supplementation program increased serum vitamin D levels in patients undergoing implant therapy, highlighting the practical value of identifying and managing deficiency prior to surgery. Although the study did not directly compare implant failure rates between supplemented and non-supplemented groups, it highlights the importance of identifying and managing vitamin D deficiency prior to implant surgery (Paz et al., 2021).

Besides systemic approaches, local application of vitamin D may also represent a promising strategy in implant dentistry. Recent clinical findings have shown that topical vitamin D3 can improve implant stability, bone density, and soft tissue healing (Ayyad et al., 2025). Nevertheless, more research is required to determine its long-term effectiveness and relevance in clinical practice.

4.5 Limitations and future research directions

The interpretation of current evidence is limited by considerable heterogeneity among studies. Differences in study design, definitions of vitamin D deficiency, supplementation protocols, and outcome measures complicate direct comparisons (Grigoraș et al., 2025; Mohsen et al., 2024).

Additionally, many studies involve relatively small sample sizes and short follow-up periods, which may limit the ability to detect long-term effects. Confounding factors such as dietary habits, sun exposure, systemic health conditions, and local bone characteristics are often not fully controlled, further contributing to variability in results (Grigoraș et al., 2025).

Future research should focus on large-scale, well-designed prospective clinical studies and randomized controlled trials to better clarify the role of vitamin D in implant dentistry. Particular attention should be given to defining optimal serum thresholds, establishing standardized supplementation protocols, and exploring individual variability, including genetic factors such as vitamin D receptor polymorphisms.

5. Conclusions

The available evidence suggests that serum vitamin D status may influence early dental implant healing, osseointegration, and peri-implant bone stability. Most included studies indicated a potentially beneficial effect of adequate serum vitamin D levels or supplementation during the early healing phase; however, the evidence remains heterogeneous and does not allow for definitive conclusions regarding implant failure risk. Importantly, both vitamin D deficiency and excessively elevated serum vitamin D levels may be associated with unfavorable implant outcomes, highlighting the importance of maintaining an optimal physiological range. From a clinical perspective, preoperative assessment of serum 25(OH)D levels may be considered in patients at increased risk of deficiency or impaired bone metabolism. Further large-scale randomized controlled trials are needed to establish clinically relevant cut-off values and standardized supplementation protocols.

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